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The Impact of Computer-Based Training on Operating and Support Costs for the AN/SQQ-89(v) Sonar System

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The U.S. Navy transitioned to computer-based training (CBT) in A and C schools in 2003 after a 2001 Revolution in Training report claimed that the Navy would realize savings in cost and training time without negatively affecting the quality of sailors arriving to the fleet. Anecdotal evidence from ship personnel suggested otherwise. This study analyzes maintenance data for the AN/SQQ-89(v) sonar system to determine whether the transition to CBT contributed to increased fleet maintenance costs. Government studies showed that the conversion to CBT was not the sole contributing factor to increased fleet maintenance costs or degraded fleet material readiness. Changes to the Navy?s training, maintenance, and manning programs during the early 2000s were all contributing factors. If the conversion to CBT were to have an effect anywhere in the Navy maintenance system, it should be seen in maintenance activities where sailors were performing maintenance on ships. Our analysis revealed that the average cost of these activities was significantly greater after CBT was implemented. This would support the anecdotal evidence that CBT was impacting the quality of maintenance on ships.

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Preface & Acknowledgements

Welcome to our Tenth Annual Acquisition Research Symposium! We regret that this year it will be a "paper only" event. The double whammy of sequestration and a continuing resolution, with the attendant restrictions on travel and conferences, created too much uncertainty to properly stage the event. We will miss the dialogue with our acquisition colleagues and the opportunity for all our researchers to present their work. However, we intend to simulate the symposium as best we can, and these *Proceedings* present an opportunity for the papers to be published just as if they had been delivered. In any case, we will have a rich store of papers to draw from for next year's event scheduled for May 14–15, 2014!

Despite these temporary setbacks, our Acquisition Research Program (ARP) here at the Naval Postgraduate School (NPS) continues at a normal pace. Since the ARP's founding in 2003, over 1,200 original research reports have been added to the acquisition body of knowledge. We continue to add to that library, located online at www.acquisitionresearch.net, at a rate of roughly 140 reports per year. This activity has engaged researchers at over 70 universities and other institutions, greatly enhancing the diversity of thought brought to bear on the business activities of the DoD.

We generate this level of activity in three ways. First, we solicit research topics from academia and other institutions through an annual Broad Agency Announcement, sponsored by the USD(AT&L). Second, we issue an annual internal call for proposals to seek NPS faculty research supporting the interests of our program sponsors. Finally, we serve as a "broker" to market specific research topics identified by our sponsors to NPS graduate students. This three-pronged approach provides for a rich and broad diversity of scholarly rigor mixed with a good blend of practitioner experience in the field of acquisition. We are grateful to those of you who have contributed to our research program in the past and encourage your future participation.

Unfortunately, what will be missing this year is the active participation and networking that has been the hallmark of previous symposia. By purposely limiting attendance to 350 people, we encourage just that. This forum remains unique in its effort to bring scholars and practitioners together around acquisition research that is both relevant in application and rigorous in method. It provides the opportunity to interact with many top DoD acquisition officials and acquisition researchers. We encourage dialogue both in the formal panel sessions and in the many opportunities we make available at meals, breaks, and the day-ending socials. Many of our researchers use these occasions to establish new teaming arrangements for future research work. Despite the fact that we will not be gathered together to reap the above-listed benefits, the ARP will endeavor to stimulate this dialogue through various means throughout the year as we interact with our researchers and DoD officials.

Affordability remains a major focus in the DoD acquisition world and will no doubt get even more attention as the sequestration outcomes unfold. It is a central tenet of the DoD's Better Buying Power initiatives, which continue to evolve as the DoD finds which of them work and which do not. This suggests that research with a focus on affordability will be of great interest to the DoD leadership in the year to come. Whether you're a practitioner or scholar, we invite you to participate in that research.

We gratefully acknowledge the ongoing support and leadership of our sponsors, whose foresight and vision have assured the continuing success of the ARP:

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The Impact of Computer-Based Training on Operating and Support Costs for the AN/SQQ-89(v) Sonar System

Diana I. Angelis, *Naval Postgraduate School*
William A. Gibson, *United States Navy*

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Michael J. Sullivan
Government Accountability Office

The Impact of Computer-Based Training on Operating and Support Costs for the AN/SQQ-89(v) Sonar System

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Abstract

The U.S. Navy transitioned to computer-based training (CBT) in A and C schools in 2003 after a 2001 *Revolution in Training* report claimed that the Navy would realize savings in cost and training time without negatively affecting the quality of sailors arriving to the fleet. Anecdotal evidence from ship personnel suggested otherwise. This study analyzes maintenance data for the AN/SQQ-89(v) sonar system to determine whether the transition to CBT contributed to increased fleet maintenance costs.

Government studies showed that the conversion to CBT was not the sole contributing factor to increased fleet maintenance costs or degraded fleet material readiness. Changes to the Navy's training, maintenance, and manning programs during the early 2000s were all contributing factors. If the conversion to CBT were to have an effect anywhere in the Navy maintenance system, it should be seen in maintenance activities where sailors were performing maintenance on ships. Our analysis revealed that the average cost of these activities was significantly greater after CBT was implemented. This would support the anecdotal evidence that CBT was impacting the quality of maintenance on ships.

Introduction

Traditionally, the majority of specialized skills training (known as "A" and "C" schools) in the Navy has taken place in a classroom setting with instructors. At the turn of the century, Navy leadership became concerned that current training programs would not adequately meet future demands. As a result, the chief of naval operations (CNO) chartered an Executive Review of Navy Training (ERNT) to review the Navy training system and recommend solutions to improve training effectiveness and meet future training demands.

The ERNT group noted that formal schoolhouse training requires a large investment in facilities, instructors, and laboratories and that future training demand would outstrip the number of billets available under the legacy schoolhouse system (Executive Review of Navy Training [ERNT], 2001). They suggested that the use of new training technologies could help meet that demand while reducing the cost of training. Motivated by these findings, the Navy established Task Force EXCEL (Excellence through Commitment to Education and Learning) to develop a continuum of lifelong learning, use a streamlined funding process and a single training authority, create a Human Performance Systems Model (HPSM), and link training and acquisition (Naval Personnel Development Command, 2002).

Part of the Navy's new strategy included the use of new training technologies such as distributed learning, computer-based training (CBT), collaborative learning, and computer-mediated learning. The Navy claimed that the introduction of CBT would reduce both training time and training costs without reducing the quality of training received (ERNT, 2001). Accordingly, CBT was introduced full-time into the training pipeline in fiscal year (FY) 2003.

A 2009 Naval Inspector General (IG) Report, *Computer Based Training*, reported that the introduction of CBT did reduce training time. However, sailors arriving to the fleet under CBT did not usually meet the required Knowledge, Skills, Abilities, and Tools (KSATs) upon reporting on board. Because of this, ships had to take the time to train sailors up to acceptable standards (Naval Inspector General, 2009). This suggests that while initial training costs may have been reduced by CBT, the overall cost of operations and maintenance, including on-the-job training (OJT), may have increased.

This study examines the impact of CBT on Navy training costs as well as operations and maintenance costs before and after the implementation of CBT. We first look at Department of the Navy (DoN) Budget Reports from FY2000 through FY2010 to determine the macro-level impact of CBT on Navy costs. At the macro level, there are many variables besides CBT that could contribute to changes in maintenance costs, including the Global War on Terror (GWOT) and increased operations tempo (OPTEMPO). However, it is impractical to isolate the impact of CBT on Navy maintenance costs at the macro level. Instead, it is necessary to look at the impact of CBT on a particular system, program, or technology. This research effort focuses on a single system, the AN/SQQ-89(v) sonar, collecting data at a level of detail that allows for the control of the various variables that might impact maintenance costs.

We start with a discussion of the Navy's classroom training system, the Revolution in Training and CBT, followed by a look at the Navy maintenance process and changes in manning and maintenance policies during the 2000s. Next, we focus on a single Navy system, the AN/SQQ-89(v) sonar system, and examine how the conversion to CBT might have affected maintenance costs in that system.

Training

Training in the Navy occurs throughout a sailor's career. After completing recruit training, sailors are sent to specialized skill training in their designated job specialty, or rating. In-rate training begins in A school, where sailors learn the particular skills specific to their job. From there, a sailor can receive additional training in C school. Once a sailor is assigned to a ship, he or she receives training for collateral duties such as quarterdeck watches, anti-terrorism/force protection watches, weapons handling, and the at-sea fire party. Additionally, sailors can expect to receive general military training in topics ranging from electrical safety to suicide prevention.

Traditional Schoolhouse Training

Until the early 2000s, in-rate training in the Navy was conducted in a formal schoolhouse setting, where instructors delivering the training are subject matter experts (SMEs) on the material they are teaching (ERNT, 2001). Typically, SMEs come from the fleet and have experience working on the equipment they are teaching about. Training is delivered in the form of lectures, and instructors are able to supplement the lecture material with tips and anecdotes from their career experiences (Naval Inspector General, 2009).

In addition to lectures, sailors can reinforce their understanding of the material through hands-on experience in a laboratory setting. In maintenance courses, students are

able to work on the exact equipment they will see in the fleet, and instructors are able to simulate equipment casualties for technicians to troubleshoot. Instructors are able to tailor the delivery of material to a class based on the students' levels of comprehension. For example, if a class has difficulty understanding a particular concept, the instructor can choose to spend more time in the lab to reinforce what is learned during the classroom portion.

There are several benefits to instructor-led training (ILT). Since a single instructor teaches a large group of students, group learning techniques can be employed that would otherwise be unavailable in one-on-one or CBT instruction. The formation of small groups within a class fosters team-building and allows students to help and teach each other. Compared to the costs of software development, testing, and hardware purchase, ILT is in some ways more cost effective, depending on class size and length of use. Additionally, the controlled classroom environment offers fewer distractions than CBT or distance learning. Finally, ILT doesn't take as long to develop as CBT. It takes approximately 34 hours to develop one hour of ILT (Chapman, 2007), while it takes approximately 220 hours to develop a standard e-learning course (Chapman, 2006).

ILT also has its disadvantages. Since everyone has different learning capabilities, some students may be more advanced and become bored while waiting for slower learners to catch up. Conversely, slow learners may have difficulty keeping up. Depending on the size and duration of the course, ILT may be more expensive than CBT.

Revolution in Training

In October 2000, the Executive Review of Navy Training (ERNT) group was charged with providing insights on how to improve and align training organizations, leverage civilian training practices, and use new technologies to provide a continuum of training for sailors. The 24-member group was comprised of military and civilian personnel, members of academia, research institutions, and industry. In 2001, ERNT released their report, *Revolution in Training: Executive Review of Navy Training Final Report.*

During their review, the ERNT group noted that the demands for training had increased. At the macro level, the training demands are driven by the Required Operational Capabilities and Projected Operating Environments (ROC/POE). ROC/POE is a tool that is used to determine specific warfighting missions for each ship. Training requirements are derived from these missions and are then used to determine specific training requirements for sailors.

Changes in the ROC/POE lead to increased ship training requirements which are passed down to the sailor level. The ERNT group noted that the finite number of seats available in the Navy schoolhouses was not able to support the increased training demands. Because of this, there were gaps in the types of training that current and/or potential sailors needed and what could be delivered.

In many cases, this resulted in billets which could not be filled because there were no sailors with the required training to fill them. During the 1990s, several other items contributed to the lack of trained sailors. First, the pool of experienced sailors had decreased due to drawdowns and retirements. Second, it was difficult to compete for trained personnel in a healthy U.S. economy, and many trained sailors were leaving for jobs in the civilian sector.

The ERNT group suggested that technology and the science of learning offered several opportunities to improve the Navy training system by reducing training time through

CBT and offering distributed learning opportunities that could be executed at the workplace. This is discussed further at the end of the report.

Computer-Based Training

Computer-based training, or CBT, is defined as "individual or group self-paced instruction using a computer as the primary training medium, to include web-delivered Navy E-Learning (NEL)" (Naval Inspector General, 2009, p. ii). In Navy A schools, students go through learning modules on a personal computer at their own pace. When students are done processing the information presented on the screen, they click "next" to proceed to the next piece of information. There are usually small knowledge assessments throughout the module, followed by a final knowledge assessment at the end of the module (Naval Inspector General, 2009, p. 7).

Because the learning is self-paced, instructors were replaced with "facilitators." Facilitators are not necessarily SMEs in the subject matter being delivered in the CBT modules. The purpose of the facilitator is "to ensure classroom rules are followed, assist with computer-related issues, and monitor student progress. They do not provide reinforcement of learning objectives or enhance retention of course material." The problem with replacing instructors with facilitators is that students cannot go to a facilitator with a question about subject material, removing the opportunity to teach when a student is confused (Naval Inspector General, 2009).

There are several advantages to CBT. The learning is self-paced and if the course is offered as distance learning, the schedule to take the course is flexible. Students can complete the course at their own paces, which generally shortens training time. Since there are no instructors involved, the message doesn't change from one person to the next (Dhanjal & Calis, 1999). In addition, the Navy was able to reduce training time using CBT, which resulted in cost savings in training manpower and infrastructure, as noted by the Navy IG (2009) and the GAO (2010).

However, the use of CBT raised concerns in the fleet about the level of knowledge of sailors reporting to ships from A schools. The inspector general (IG) noted that sailors arriving to the fleet under CBT did not usually meet the required KSAT standards and were unfamiliar with the equipment they would be working on and the tools they would need to use. Because of this, ships had to take the time to train sailors up to acceptable standards. In fleet interviews, some commands reported that qualification time was nearly double what it was before the introduction of CBT (Naval Inspector General, 2009). The GAO reports in 2010 and 2011 made similar observations and concluded that the change to CBT had a negative impact on readiness.

The Navy IG and GAO reports found that while the Navy's use of CBT resulted in cost and training time savings, the quality of sailor reporting to the fleet was not as well prepared as ILT-trained sailors of the past. The result is that poorly-trained sailors may have contributed to declining material readiness in the fleet. The next section of this study examines Navy maintenance practices and highlights the findings of the *2010 Fleet Review Panel on Surface Force Readiness* report.

Maintenance

Navy maintenance occurs on three levels: organizational level (O-level), intermediate maintenance (IM) activities, and depot level. This section of the study discusses all three maintenance levels. Additionally, this section discusses changes made to the maintenance process in 2003 which were reported on in the *2010 Fleet Review Panel on Surface Force Readiness* (known as the Balisle Report for its chairman, Vice Admiral [VADM, Retired]

Phillip Balisle), a report that discussed declining fleet readiness as a result of changes to training, maintenance, and manning policies in the early 2000s.

Shipboard maintenance begins with the Planned Maintenance System (PMS). PMS is governed by Naval Sea Systems Command (NAVSEA; 2003) Instruction 4790.8B, *Ship's Maintenance and Material Management (3-M) Manual*. The instruction outlines the requirements for PMS on shipboard systems and equipment. The purpose of PMS is to provide ships with the means to plan, schedule, and perform preventive maintenance onboard and to identify potential equipment problems before the equipment fails.

If corrective maintenance is required, the maintenance is reported, scheduled, and performed through O-level shipboard maintenance. Ship maintenance actions are reported in Navy Visibility and Management of Operating and Support Costs (VAMOSC), under Unit Level Consumption and Manhours—Organizational Corrective Maintenance.

Intermediate maintenance (IM) is "normally performed by Navy personnel onboard tenders, repair ships, Shore Intermediate Maintenance Activities (SIMAs), aircraft carriers, and fleet support bases" (Naval Sea Systems Command, 2003, p. I-5). IM jobs are deferred corrective maintenance jobs that are beyond the capability of the ship's force and are sent off-ship for completion. IM is tracked in Navy VAMOSC under Maintenance—Intermediate.

Depot-level maintenance "requires major overhaul or a complete rebuilding of parts, assemblies, subassemblies, and end items, including the manufacturing of parts, modifications, testing, and reclamation" (Naval Sea Systems Command, 2003, p. I-5). Depot maintenance is reported in Navy VAMOSC under Maintenance and Modernization—Depot, Other Depot.

In 2009, VADM (Ret.) Phillip Balisle was directed to conduct a Fleet Review Panel (FRP) of surface force material readiness. The report noted that 4,052 billets were removed from Navy ships from 2001–2009. While billets were removed from ships, requirements such as maintenance, damage control watches, training, and in-port duties were not reduced (Balisle, 2010). The shortcomings of CBT described in the previous section exacerbated the problems experienced with manning reductions since sailors were not arriving on board with the right KSATs. The result was undermanned ships with poorly trained sailors with not enough time or know-how to perform routine maintenance actions.

In addition to reduced fleet manning, shore facilities also received manning cuts. This means that maintenance that was intended for intermediate maintenance activities was pushed back to ship personnel, which were undermanned and poorly trained. In addition to the shrinking shore workforce, the amount of time the ships were available was shortened from 15 weeks to nine weeks (Balisle, 2010). These actions resulted in equipment being out of commission for longer periods of time.

Finally, the 2010 Balisle report noted that changes in PMS were made because ships couldn't meet maintenance requirements due to reduced manning. Maintenance requirements were either eliminated or extended in periodicity. The intent was to shift maintenance requirements to shore facilities, but since manning was reduced ashore, many requirements went away completely. The elimination and extension of maintenance requirements can lead to more opportunities for equipment to become inoperable, resulting in degraded fleet readiness (Balisle, 2010).

The Navy introduced several major changes to training, maintenance, and manning policies during the early part of the 2000–2010 decade. The Balisle report found that training was a factor, but certainly not the only factor, that led to degraded fleet readiness. Manning reductions would have led to cost savings in the military personnel budget, but the impact of

the reductions may have resulted in maintenance cost increases in future budgets due to deferred maintenance actions, thus confounding the effect of CBT. Similarly, changes in maintenance policies may have impacted maintenance costs in future years. At a macro level, the impact of CBT is impossible to tease out (see Gibson, 2012, for an examination of Navy training, operations, and maintenance budgets between 2000 and 2012). For this reason, we decided to examine one system in particular, the AN/SQQ-89(v) sonar system, in hopes that we could separate the two factors.

AN/SQQ-89(v) Sonar System

To examine the effect of CBT on rising maintenance costs, this study will focus on the operating and support (O&S) costs of a single Navy system, the AN/SQQ-89(v) sonar system, and look at how the conversion to CBT affected maintenance costs in that system. An analysis by Gibson (2012) showed that manning levels for sonar technicians did not change significantly from FY2000–FY2010, effectively eliminating manning as a contributor for the AN/SQQ-89 O&S costs and focusing the study on training and maintenance.

The AN/SQQ-89(v) surface ship Anti-Submarine (ASW) Warfare combat system (referred to as “the 89” in the rest of this paper) is an integrated network of sonar systems designed to search, detect, classify, and engage ASW threats. The system is currently installed on CG-47 class cruisers, DDG-51 class destroyers, and FFG-7 class frigates. The 89 uses a variety of sensors that can transmit (active) and receive (passive) acoustic data in order to detect and classify threats. Data from the sensors can be correlated and targets can be localized using Target Motion Analysis (TMA) to generate a firing solution for weapons systems (Jane’s Information Group, 2010).

The 89 system consists of 15 different variants. Variants differ based on the sensors chosen and the version of each sensor. In this report, only variants 2, 3, 4, 6, 7, and 9 were studied. These variants were chosen because they were on board ships prior to the introduction of CBT into the sonar training pipeline (2003) and remained on board after CBT was introduced. This allows for analysis of ship-maintenance trends both prior to and after the introduction of CBT. A list of ships per variant is given in Table 1.

Table 1. List of Ships and AN/SQQ-89(v) System Variants Used in This Study

(V)2	SHIP	HOMEPORT
CG 55	LEYTE GULF	Norfolk, VA
FFG 8	MCINERNEY	Mayport, FL
FFG 28	BOONE	Mayport, FL
FFG 29	STEPHEN W GROVES	Mayport, FL
FFG 32	JOHN HALL	Mayport, FL
FFG 33	JARRET	San Diego, CA
FFG 36	UNDERWOOD	Mayport, FL
FFG 38	CURTS	San Diego, CA
FFG 39	DOYLE	Mayport, FL
FFG 40	HALYBURTON	Mayport, FL
FFG 41	MCCLUSKY	San Diego, CA
FFG 42	KLAKRING	Mayport, FL
FFG 43	THACH	San Diego, CA
FFG 45	DE WERT	Mayport, FL
FFG 46	RENTZ	San Diego, CA
FFG 47	NICHOLAS	Norfolk, VA
FFG 48	VANDEGRIFT	San Diego, CA
FFG 49	ROBERT G BRADLEY	Mayport, FL
FFG 53	HAWES	Norfolk, VA
FFG 55	ELROD	Norfolk, VA
FFG 56	SIMPSON	Mayport, FL
FFG 57	REUBEN JAMES	Pearl Harbor, HI
FFG 58	SAMUEL B ROBERTS	Mayport, FL
FFG 59	KAUFFMAN	Norfolk, VA
FFG 60	RODNEY M. DAVIS	Everett, WA
FFG 61	INGRAHAM	Everett, WA

(V)3	SHIP	HOMEPORT
CG 56	SAN JACINTO	Norfolk, VA
CG 57	LAKE CHAMPLAIN	San Diego, CA
CG 58	PHILIPPINE SEA	Mayport, FL

(V)4	SHIP	HOMEPORT
DDG 51	ARLEIGH BURKE	Norfolk, VA

(V)7	SHIP	HOMEPORT
CG 66	HUE CITY	Mayport, FL
CG 67	SHILOH	Yokosuka, Japan

(V)9	SHIP	HOMEPORT
FFG 37	CROMMELIN	Pearl Harbor, HI
FFG 50	TAYLOR	Mayport, FL
FFG 51	GARY	San Diego, CA
FFG 52	CARR	Norfolk, VA
FFG 54	FORD	Everett, WA

(V)6	SHIP	HOMEPORT
CG 68	ANZIO	Norfolk, VA
CG 69	VICKSBURG	Mayport, FL
CG 70	LAKE ERIE	Pearl Harbor, HI
CG 71	CAPE ST GEORGE	San Diego, CA
CG 72	VELLA GULF	Norfolk, VA
DDG 52	BARRY	Norfolk, VA
DDG 53	JOHN PAUL JONES	San Diego, CA
DDG 54	CURTIS WILBUR	Yokosuka, Japan
DDG 55	STOUT	Norfolk, VA
DDG 56	JOHN S. MCCAIN	Yokosuka, Japan
DDG 57	MITSCHER	Norfolk, VA
DDG 58	LABOON	Norfolk, VA
DDG 59	RUSSELL	Pearl Harbor, HI
DDG 60	PAUL HAMILTON	Pearl Harbor, HI
DDG 61	RAMAGE	Norfolk, VA
DDG 63	STETHEM	Yokosuka, Japan
DDG 64	CARNEY	Mayport, FL
DDG 65	BENFOLD	San Diego, CA
DDG 66	GONZALEZ	Norfolk, VA
DDG 67	COLE	Norfolk, VA
DDG 68	THE SULLIVANS	San Diego, CA
DDG 69	MILIUS	San Diego, CA
DDG 70	HOPPER	Pearl Harbor, HI
DDG 71	ROSS	Norfolk, VA
DDG 72	MAHAN	Norfolk, VA
DDG 73	DECATUR	San Diego, CA
DDG 74	MCFAUL	Norfolk, VA
DDG 75	DONALD COOK	Norfolk, VA
DDG 76	HIGGINS	San Diego, CA
DDG 77	O'KANE	Pearl Harbor, HI
DDG 78	PORTER	Norfolk, VA

All sonar technicians–surface (STGs) attend STG A school. At A school, students learn the basic principles of the STG rating including oceanography and principles of sound. Following A school, STGs are sent to different courses depending on whether they are operators or operator/maintainers. STGs who are strictly operators are sent to a sonar operator course, where they learn how to operate the specific 89 variant of the ship to which they will be sent. Maintainers are sent to C school, where they learn the technical skills required to maintain the equipment they will work on upon reporting to their ship (Navy Personnel Command, 2012).

CBT was introduced full-time into the training pipeline in FY2003, after the recommendations of the ERNT report (Naval Inspector General, 2009). Data were not available to show how STG course lengths were affected by the conversion to CBT. The 2009 Navy IG report examined the course lengths of 22 A and C schools for ILT and CBT and found that on average, CBT course lengths were 26% shorter than ILT course lengths (Naval Inspector General, 2009). This study focuses on FY1999 through FY2010 to capture data prior to and after the introduction of CBT. Initially, FY1995 through FY1998 were also considered, but there were not enough data available during this time frame for most data categories. The raw data provided were analyzed to reveal relationships between selected data sets.

Program Executive Office Integrated Warfare System 5 (PEO IWS5) provided a list of ships equipped with the AN/SQQ-89(v) sonar system. The list included ship class, ship name, hull number, homeport, and 89 variant number. Only ships with AN/SQQ-89(v) variants on board both before and after implementation of CBT were considered. The initial list provided by PEO IWS5 included all ships of the CG-47, DD-963, DDG-51, and FFG-7

classes. To narrow the ship list to match the scope of our study, ships were removed from the data set if

- the ship was decommissioned during the FY1995-FY2006 time frame,
- the ship received a variant upgrade,
- the ship was commissioned FY2000 or later, or
- the ship was outfitted with a variant introduced after FY2003.

Using these criteria, the ship list was reduced to 68 ships. VAMOSC provided O&S cost data, underway steaming days, and selected non-cost data for ships equipped with the AN/SQQ-89 sonar system covering FY1995 through FY2010. Cost figures were given in then-year and constant FY2011 dollars.

In addition to the overall 89 system data, detailed ship data were available for the selected ships. Non-cost data included number of personnel trained, maintenance manhours, and number of maintenance actions. The data were used to calculate average time (in manhours) spent per maintenance action. These numbers were calculated to determine training and maintenance trends pre- and post-CBT (see Figure 1). For instance, if the average time spent per maintenance action increased, it could suggest a backlog of maintenance or a lack of technical competence in performing a maintenance action. Prior to CBT, manhours spent per maintenance action were trending upward; after the introduction of CBT, manhours per maintenance action remained relatively flat. This suggests that manhours per maintenance action may have reacted positively to the conversion to CBT; however, this assumes that the types of maintenance actions performed remained relatively constant.

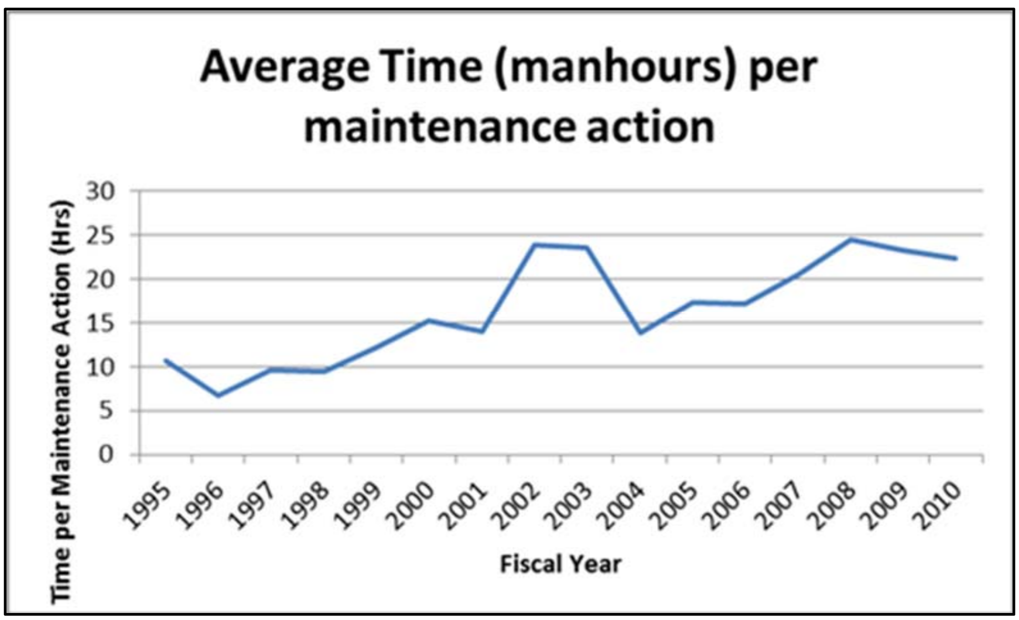

Figure 1. Manhours Spent per Maintenance Action

Single-factor regression analysis was performed to explore the relationship between total training cost and the O&S variables provided by Navy VAMOSC. Unit Level Consumption, IM, Equipment Rework, and Depot Maintenance were selected as variables to determine whether changes in training costs resulted in increased maintenance costs. The selected variables represent organizational-level, intermediate, and depot-level

maintenance. Unit Level Consumption is a summation of Organizational Repair Parts, Replenishment Spares, and Logistics Center (LOGCEN) exchanges. Equipment Rework is a summation of contractor and government Program Office rework costs. IM is a summation of afloat and ashore IM labor costs and ashore IM materials costs. Depot Maintenance is a summation of private and public shipyard depot costs. Training (Total) is a summation of Program Office and NETPDTC training costs. The results are shown in Table 2.

Table 2. Regression Analysis—O&S Components

	R^2
Unit Level Consumption	0.033
Equipment Rework	0.002
Intermediate Maintenance	0.348
Depot-Level Maintenance	0.208

In this case, regression analysis shows that none of the factors selected have a strong relationship to total training cost, suggesting that if maintenance costs are related to training costs in the STG rating, there are other factors not identified in this study that are having an effect. It is interesting to look at the relationship of IM costs and training dollars in a scatter diagram (Figure 2).

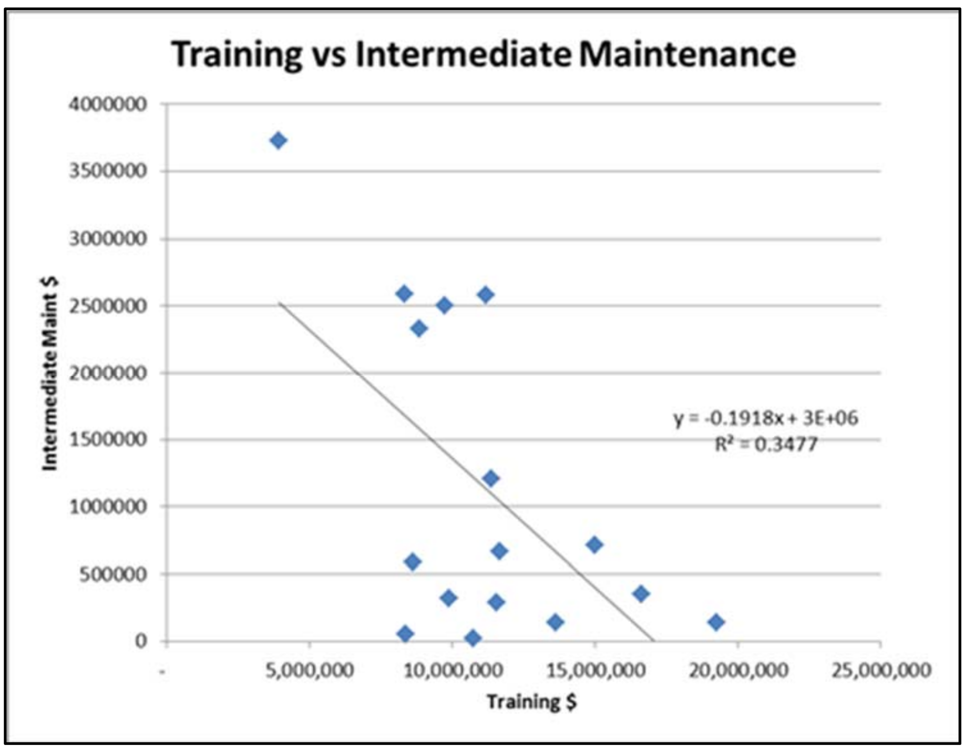

Figure 2. Training vs. Intermediate Maintenance Scatter Plot

Figure 2 suggests that there may be a weak relationship between training dollars and intermediate maintenance costs and that this warrants further investigation. Specifically, the

plot suggests that as training costs increase, intermediate maintenance costs decrease. This would support the hypothesis that when less money is spent on training (as a result of switching to CBT), the maintenance costs will increase.

Graphical analysis of several data categories indicated noticeable changes after the introduction of CBT. For example, Labor Ashore—Intermediate Maintenance Manhours showed significant change (see Figure 3).

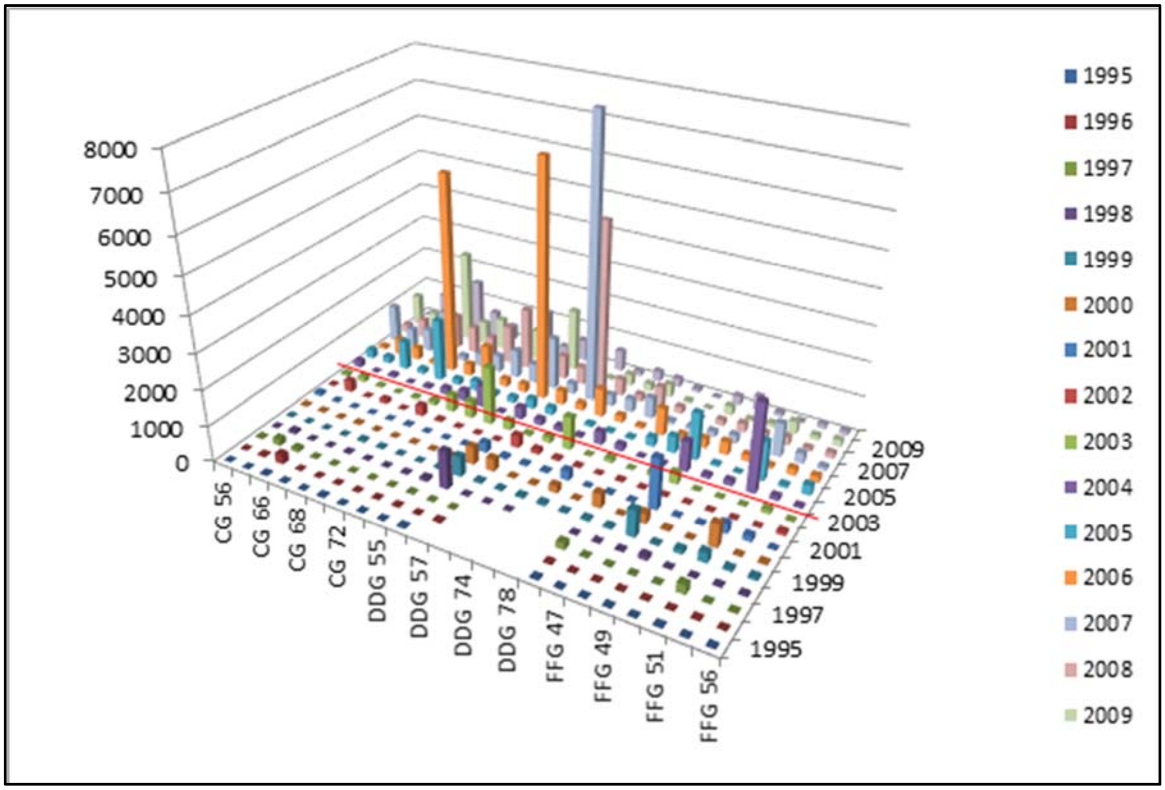

Figure 3. Labor Ashore—Intermediate Maintenance Manhours

The figure shows the number of manhours spent on IM for selected ships from FY1995 through FY2010. Beginning in FY2004, the IM manhours increased significantly for the selected DDG-51 and CG-47 class ships. While this may be partially explained by changes to Navy maintenance policy described earlier, it corroborates the evidence suggested in Figure 2, namely that as CBT is introduced and training costs decrease, intermediate maintenance hours and cost increase. This trend was not as evident, however, for the FFG-7 class. This may be explained by funding of the ship class, since many of these ships belong to the Naval Reserve Force and it is likely that their funding levels did not change throughout the period studied.

Paired t-tests were conducted to determine whether the means of paired observations (selected ships pre- and post-CBT) were different. The null hypothesis is that there is no significant difference in the means before and after the introduction of CBT. The alternate hypothesis is that there is a significant difference between the means due to CBT. A negative t-statistic indicates that the pre-CBT mean was smaller, while a positive t-statistic indicates that the post-CBT mean was smaller. Response variables used in this study were corrective organizational and IM actions, organizational parts cost, exchanges LOGCEN cost, manhours organizational labor, and labor ashore IM manhours (see Table 3).

Table 3. Paired t-Test Results

Variable	degrees freedom		Number of obs.	Mean	t statistic	p-value
Corrective org. & IM actions	786	before CBT	335	61.43	-6.61	0.0000
		after CBT	458	85.10		
Organizational parts cost	790	before CBT	336	6914.4	-4.07	0.0000
		after CBT	466	9539.6		
Exchanges LOGCEN cost	563	before CBT	238	43752	-6.30	0.0000
		after CBT	328	72178		
Manhours org. labor	779	before CBT	335	739.9	-7.03	0.0000
		after CBT	466	1208.7		
Labor ashore IM manhours	206	before CBT	109	107.51	-5.17	0.000
		after CBT	149	357.17		

In all cases, the p-values were less than 0.01, indicating a significant difference between the means pre- and post-CBT. This suggests that the introduction of CBT had a statistically significant impact on several measures of maintenance activity and cost.

Interestingly, the number of maintenance actions (organizational and IM) increased, even though changes in Navy maintenance policies would have initially led to fewer maintenance actions. Since we report the average over several years, it is possible that the expected increase in future maintenance actions was part of the observed mean after CBT. It is also likely that changes in operating tempo (due to the GWOT) had a significant impact on this variable as well, so it is not possible to isolate the effect of CBT on corrective maintenance actions.

Most interesting are the three categories related to maintenance actions performed by sailors at the ship level: organizational parts cost, exchanges LOGCEN cost, and manhours organizational labor. If the conversion to CBT were to have an effect anywhere in the Navy maintenance system, it would be at maintenance activities where sailors were performing maintenance on ships. This data would support the anecdotal evidence provided by ship operators that CBT training would also impact labor ashore IM manhours (in IM facilities); however, a confounding variable for IM is that several shore-based IM facilities were closed and shore-based IM billets for sailors were eliminated.

Conclusion and Areas for Further Research

In 2001, ERNT released its report, Rev*olution in Training: Executive Review of Navy Training Final Report*, which led to a major overhaul in the U.S. Navy's training practices, including the use of CBT in A and C schools. While government studies of the Navy's CBT training confirmed that the transition to CBT resulted in shorter training times and cost savings, sailors reporting to the fleet were not as well prepared as classroom-trained sailors of the past, and extensive OJT, supervision, and assistance in performing basic maintenance tasks were required to bring CBT-trained sailors up to speed.

During the same period of time that CBT was being implemented, the U.S. Navy reorganized its maintenance program and reduced total manning levels on ships, even though ship requirements did not change, meaning that ships had to do more work with fewer personnel. Many maintenance requirements were deferred or eliminated on ships with

the expectation that shore facilities would pick up the slack, but shore facilities also experienced manning reductions. As a result, less planned maintenance was being performed on equipment, which increased opportunities for equipment failure and decreased fleet material readiness.

This study looked at costs from a systems perspective, considering not only the cost of training but also the cost of maintenance. We asked the following question: If sailors trained with CBT had lower knowledge and skill levels, did this contribute to increased operations and maintenance costs?

Unfortunately, there were too many confounding variables that could have affected operation and maintenance costs during this period of time to draw any conclusions about the effect of CBT on maintenance costs from the Navy level. Instead, we focused on a single Navy system, the AN/SQQ-89(v) sonar system, to examine the effects of the conversion to CBT on maintenance.

The results of the study revealed several pieces of useful information. Regression analysis indicates a weak relationship between decreasing in training costs and an increasing in IM costs. In addition, paired t-tests showed that the conversion to CBT may have led to increases in corrective organizational and IM actions, organizational parts cost, exchanges LOGCEN cost, manhours organizational labor, and labor ashore IM manhours. Of particular interest were results for manhours organizational labor, organizational parts cost, and exchanges LOGCEN cost, all associated with maintenance performed by sailors at the unit (ship) level, because conversion to CBT training would be most noticeable at maintenance activities where sailors are performing the maintenance.

As the Navy IG, GAO, and Balisle reports suggest, there are several factors that have contributed to declines in fleet readiness. Most notably, the simultaneous combination of changes in training, maintenance, and manning policies appear to have had lasting negative impacts, including rising fleet maintenance costs. The data analysis performed in this study shows that the change to CBT was statistically significant when compared to several maintenance variables, but it is also likely that changes to all three areas (training, maintenance, and manning) had collective negative effects which go much further than rising maintenance costs and actions. It is clear that policy changes in the 2000s impacted fleet readiness in a negative manner, but no clear conclusions can be drawn about the specific impact of CBT on total system cost from the data examined in this study.

Because the data collected can be characterized as panel data, statistical analysis that recognizes the panel nature of the data will be performed and reported in another paper. It may be useful to study the impacts of the conversion to CBT on other Navy systems. From a training perspective, the lack of measures of effectiveness for training may prove frustrating in drawing any conclusions, but from a cost perspective, it may be possible to gain further insight into the types of cost most affected by CBT.

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